

Audio transmission system having an improved encoder.

The present invention relates to a transmission system comprising a transmitter having an audio encoder, said audio encoder comprises segmenting means for dividing an input audio signal into subsequent signal segments, the encoder further comprises track determining means for determining linked signal components present in subsequent signal segments, the transmitter further comprises transmit means for transmitting a signal
5 representing said linked signal components via a transmission medium to a receiver, said receiver comprises receiving means for receiving the signal representing the signal components from the transmission medium, and a decoder for deriving a reconstructed audio signal from said signal representing the signal components.

10 The invention further relates to a transmitter, an encoder, a coding method, a tangible medium, carrying a computer program and a signal, carrying a computer program.

A transmission system according to the preamble is known from US 4,885,790.
15 Such transmission systems and audio encoders are used in applications in which audio signals have to be transmitted over a transmission medium with a limited transmission capacity or have to be stored on storage media with a limited storage capacity. Examples of such applications are the transmission of audio signals over the Internet, the transmission of audio signals from a mobile phone to a base station and vice versa and storage of audio signals on a
20 CD-ROM, in a solid state memory or on a hard disk drive.

Different operating principles of audio encoders have been tried to achieve a good audio quality at a modest bit rate. In one of these operating methods, an audio signal to be transmitted is divided into a plurality of segments, having fixed or segment dependent length of 5 - 50 ms. In each of said segments the audio signal is represented by a plurality of
25 signal components, which can be sinusoids that are defined by their amplitudes, their frequencies and possibly their phases.

The transmitting means transmits a representation of the amplitudes and frequencies of the signal components to the receiver. The operations performed by the transmitter can include, channel coding, interleaving and modulation.

The receiving means receive a signal representing the audio signal from a transmission channel and performs operations like demodulation, de-interleaving and channel decoding. The decoder obtains the representation of the audio signal from the receiver and derives a reconstructed audio signal from it by generating a plurality of sinusoids as described
5 by the encoded signal and combining them into an output signal.

In an audio signal often there is a relation between the signal components of the present signal segment and the previous segment. The audio signal can e.g. include a frequency sweep of a sinusoidal component having a duration of a plurality of signal segments. The presence of such kind of signals can be exploited in the encoding process by
10 differentially encoding the frequency and amplitude of signal segments following the first signal segment. This means that instead of the frequency and the amplitude of the signal segment, only the difference between the frequency of the signal component in the present signal segment and in the previous signal component are transmitted. The same can be done with the amplitudes of two subsequent segments.

In order to do so, the encoder comprises track determining means for determining which signal components are linked. In the transmission system according to the above mentioned US patent, the frequency difference between signal components in the present frame and in the previous frame are used to determine which frequency components are linked and which are not. However, experiments have shown that this does not always
15 results in an optimum quality of the reconstructed audio signal.

The object of the present invention is to provide a transmission system having an improved quality of the reconstructed audio signal.

25 To achieve said object, the transmission system according to the preamble is characterized in that the tracking means comprises selection means for selecting linked signal components resulting in a minimum error measure between a synthetic audio signal determined on basis of said linked signal components and said input audio signal.

By trying a plurality of candidate linked signal components and selecting that
30 set of linked signal components resulting in a minimum error measure, an improved quality of the reconstructed audio signal is obtained. The error measure can be e.g. the mean squared error or a perceptually weighted error measure. It is observed that it is always necessary to actually generate the synthetic speech signal, but that it is possible to use analytical

methods to determine the optimum parameters of the signal components from the expression of the error signal.

An embodiment of the invention is characterized in that the encoder comprises synthesizing means for deriving the synthetic signal on basis of at least one parameter of said candidate linked signal components in two subsequent signal segments.

By deriving the synthetic signal on basis of at least one parameter (frequency, amplitude) of two subsequent signal segments, the change of said parameters in the synthetic signal is more smooth, which corresponds better to the properties of the input audio signal.

A further embodiment of the invention is characterized in that the synthesizing means are arranged for deriving interpolated signal component parameters from signal component parameters corresponding to at least two subsequent signal segments and in that the synthesizing means are arranged for deriving the synthetic signal on basis of the interpolated signal component parameters.

By using interpolated signal component parameters from signal component parameters of two (or more) subsequent signal segments is a naturally sounding synthetic audio signal is obtained.

A still further embodiment of the invention is characterized in that the tracking means comprise pre-selection means for selecting a limited number of candidate linked signal components from all possible linked signal components.

By performing a pre-selection before the actual selection of the linked signal components, it is obtained that the required computational resources are substantially reduced.

A still further embodiment of the invention is characterized in that the pre-selection means are arranged to select as candidate linked signal components signal components having a frequency difference smaller than a predetermined value.

A suitable way of pre-selecting the candidate signal components is the selection of candidate signal components having only a relative small frequency difference. The frequency difference to be allowed is a trade-off between quality and computational complexity. It is however observed that allowing frequency differences above a given value the quality of the reconstructed speech signal hardly improves.

An alternative embodiment of the present invention is characterized in that the tracking means are arranged for extending tracks on the basis of the parameters of linked signal components already determined.

By extending the current track by means of an extrapolation, the complexity of the track determining means is substantially reduced, because the process of trying a large number of candidate signal components can be dispensed with.

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The present invention will now be explained with reference to the drawings.

Fig. 1 shows a transmission system in which the present invention can be applied.

Fig. 2 shows a first embodiment of an encoder according to the invention for use in the transmission system according to Fig. 1.

Fig. 3 shows a second embodiment of an encoder according to the invention for use in the transmission system according to Fig. 1.

Fig. 4 shows a possible implementation of the tracking block 44 to be used in the encoder according to Fig. 3.

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In the transmission system according to Fig. 1, the audio signal to be transmitted is applied to an encoder 4 in a transmitter 2. The encoder 4 encodes the input signal as tracks of linked signal components. Said tracks can be represented by a start frequency, a start amplitude and a start phase for the first signal segment, followed by frequency and amplitude differences for the next segments of the track.

A signal representing said tracks is applied to the transmit means 6. The operation of the transmit means 6 can include channel coding, interleaving and modulation. The output of the transmitter 2 is applied to the transmission medium (or recording medium) 8 for transmission to the receiver 10. In the receiver 10 the signal from the received signal is applied to the receive means 12. The operations of the receive means 10 can include demodulation, de-interleaving and channel decoding. The output of the receive means 12 is connected to an input of a decoder 14 which is arranged for decoding the encoded audio signal. The operation principle of the decoder 14 is described in the above mentioned US patent.

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In the encoder 4 according to Fig. 2, the input signal is applied to segmenting means 20 that divide the input signal in signal segments having fixed or signal dependent segment lengths ranging from 5 – 50 ms. The segments can be partly overlapping, but it is also possible that the segments have no overlap. The segmentation means 20 select a part of the

signal comprising data that is input to the spectral analyzer 22 and data that is input for the closed loop tracking block 44. The appropriate data in either unit is obtained by windowing in the respective units. The segmentation means 20 also generates time markers T_k , marking the instance in the current signal segment corresponding to the instantaneous tracking parameters that are to be calculated on basis of the current signal segment, T_{k-1} corresponds to the instance in the current segment at which the instantaneous tracking parameters have been calculated in the previous iteration. Parameters obtained after closed loop tracking in the k^{th} segment are represented using the subscript k e.g. A_k . The output of the segmentation means 20 is connected to an input of a spectral analyzer 22 and to a first input of a subtractor 36.

The spectral analyzer 22 performs a coarse determination of the frequency spectrum of its input signal. This frequency spectrum forms the basis for determining the linked signal components. The coarse search performed by the spectral analyzer 22 can be based on a moderate size FFT followed by selecting the major peaks in the amplitude spectrum. The output signal of the spectral analyzer 22 is passed to component identification means 24, which perform a fine search for the parameters of the signal components. This fine search can be done in the neighborhood of the major peaks determined by the spectral analyzer 22 to obtain more accurate estimates of the parameters (amplitude, frequency and phase). Starting values for the amplitude and the frequency for the different signal components can be determined from the amplitude and the frequency of the corresponding peaks in the amplitude spectrum.

The output signal of the component identification means 24 is passed to a first input of the tracking means 28 and to a delay element 26 which has a delay of one frame period. The output of the delay element 26 is connected to a second input of the tracking means 28. The tracking means 28 starts with determining a limited number of candidate linked components. The selection of the limited number of candidate linked components can be based on the amplitude and frequency difference. For each signal component of the previous frame, all components in the current frame having a frequency and amplitude difference smaller than predetermined threshold values are added to a table of candidate linked components.

Threshold values may be set on the basis of available amplitude and frequency data, and additionally on the update rate, i.e. $1/(T_k - T_{k-1})$. Consequently, a table comprising a plurality of sets each consisting of two linked signal components is obtained. An example of such a table is given below.

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| | $f_{1,k}=149$ | $f_{2,k}=220$ | $f_{3,k}=289$ | $f_{4,k}=361$ | $f_{5,k}=428$ | $f_{6,k}=500$ | $f_{7,k}=579$ |
|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| $f_{1,k-1}=131$ | x | x | | | | | |
| $f_{2,k-1}=255$ | x | x | x | x | | | |
| $f_{3,k-1}=380$ | | | x | x | x | | |
| $f_{4,k-1}=495$ | | | | | x | x | X |
| $f_{5,k-1}=594$ | | | | | | x | X |

The amplitudes and frequencies of the signal components in each set are applied to a synthesizer 32 for deriving a synthetic audio signal from the linked signal components.

- 5 The synthetic audio signal $c_{i,j}$, linking the i th component of Frame $k-1$ with the j th component of Frame k , can be calculated by using linear interpolation of the frequencies and amplitudes between the boundaries of the frames. The synthetic signal corresponding to one track i,j can be calculated according to:

$$c_{i,j} = M[n] \cdot \cos\left(\frac{\beta}{2}(n - T_{k-1})^2 + \theta_{i,k-1}(n - T_{k-1}) + \varphi\right); T_{k-1} \leq n \leq T_k \quad (1)$$

In (1) $M[n]$ is given by:

$$M[n] = \frac{T_k - n}{T_k - T_{k-1}} A_{i,k-1} + \frac{n - T_{k-1}}{T_k - T_{k-1}} A_{j,k} \quad ; \quad T_{k-1} \leq n \leq T_k \quad (2)$$

- 10 And β is equal to:

$$\beta = \frac{\theta_{j,k-1} - \theta_{i,k}}{T_k - T_{k-1}} \quad (3)$$

where $\theta = 2\pi f / f_s$. The phase φ can be set to $\phi_{i,k-1}$, which is the phase at the end of the previous frame. The phase φ can also be derived from a phase value $\phi_{i,k}$ resulting in a minimum error measure.

- 15 An alternative to the synthesizer sketched above can for instance be the well-known overlap add synthesizer.

- The output of the synthesizer 32 is connected to a second input of the subtractor 36. The subtractor 36 determines the difference between the output signal of the segmentation means 20 and the output signal of the synthesizer 32. The output of the subtractor 36 is connected to an input of a MSE unit 34. This MSE unit 34 determines a mean square value of the output of the subtractor 36 over one frame. Optionally, the MSE unit 34 comprises a weighting filter for perceptually weighting the previously determined mean square value. The output of the MSE unit 34 is connected to a third input of the tracking means 28.

The tracking means 28 use the output signal of the MSE unit 34 to determine which combination of sets of linked signal components results in the smallest output signal of the MSE unit 34. This can be done by performing a full synthesis for all possible combinations of links, but it is also possible to perform a sub-optimal search which requires substantially less computational resources. In this sub-optimal search the synthesis is performed for one component only, and the mean squared error between the input signal and said synthetic component is calculated. This is done for all possible tracks, and a so-called error matrix is constructed. In this matrix all possible tracks are identified together with their corresponding error. Below an example of such a matrix is displayed.

| | $f_{1,k}=149$ | $f_{2,k}=220$ | $f_{3,k}=289$ | $f_{4,k}=361$ | $f_{5,k}=428$ | $f_{6,k}=500$ | $f_{7,k}=579$ |
|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| $f_{1,k-1}=131$ | 52876 | 62929 | | | | | |
| $f_{2,k-1}=255$ | 76778 | 90541 | 55049 | 69752 | | | |
| $f_{3,k-1}=380$ | | | 80849 | 89816 | 63016 | | |
| $f_{4,k-1}=495$ | | | | | 70948 | 74605 | 69535 |
| $f_{5,k-1}=594$ | | | | | | 73881 | 70260 |

In the matrix only the errors are included for the components corresponding to the preselected links.

Although in the example shown above all links are shown, it is possible to leave out the links which cause an increase of the error instead of a decrease. When the possible links are resolved, it must be the case that a signal component in the current frame has only one single corresponding component in the previous frame, and that a signal component in the previous frame has only one single corresponding component in the current frame. In the above matrix this means that rows and columns may not have multiple entries.

One possible sub-optimal way of finding the final is to first select the element in each column having the smallest error, and subsequently selecting the element in each row having the smallest error. After selecting the single elements in the columns, the matrix changes into:

| | $f_{1,k}=149$ | $f_{2,k}=220$ | $f_{3,k}=289$ | $f_{4,k}=361$ | $f_{5,k}=428$ | $f_{6,k}=500$ | $f_{7,k}=579$ |
|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| $f_{1,k-1}=131$ | 52876 | 62929 | | | | | |
| $f_{2,k-1}=255$ | | | 55049 | 69752 | | | |
| $f_{3,k-1}=380$ | | | | | 63016 | | |
| $f_{4,k-1}=495$ | | | | | | | 69535 |
| $f_{5,k-1}=594$ | | | | | | 73881 | |

After subsequently selecting the single elements in the columns, the following final link matrix is obtained.

| | $f_{1,k}=149$ | $f_{2,k}=220$ | $f_{3,k}=289$ | $f_{4,k}=361$ | $f_{5,k}=428$ | $f_{6,k}=500$ | $f_{7,k}=579$ |
|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| $f_{1,k-1}=131$ | 52876 | | | | | | |
| $f_{2,k-1}=255$ | | | 55049 | | | | |
| $f_{3,k-1}=380$ | | | | | 63016 | | |
| $f_{4,k-1}=495$ | | | | | | | 69535 |
| $f_{5,k-1}=594$ | | | | | | 73881 | |

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It is also possible to start with selecting the element in each row having the smallest error and subsequently selecting the element in each column having the smallest error. It is also possible that both possibilities are tried, and the results of the selection method leading to the smallest mean squared error (= the sum of all matrix elements) are chosen.

10 At the end of the procedure the tracks to be continued are available. The signal components in the previous frames that are not linked are either the end of a track or isolated points. The components in the current frame that could not be linked are either a newly appearing track or an isolated point. The inclusion of the parameters of the isolated points in the signal to be transmitted can be based on subjective measures such as masking threshold or
 15 on objective measures such as reduction in the error or a combination of both. Since inclusion of these isolated components also has an impact on the bitrate, the bit budget can also be considered in the process.

After the selection means have selected the linked signal components and the isolated points to be transmitted, signals representing the tracks of linked components are
 20 applied to a multiplexer 30 which combines them into a multiplex signal which is suitable for transmission.

In the encoder 4 according to Fig. 3, the segmentation unit 20, the function of which has already been described, selects a part of the signal comprising data that is input to the spectral analyzer 22 and data that is input for the closed loop tracking block 44. The appropriate data in either unit is obtained by windowing in the respective units.

5 A memory unit 32 holds a description relevant information from the previous segment $k-1$. The control unit 40 uses the input signal received from the memory unit 32 and possibly the input from the spectral analyzer 22 to make an estimate of track continuation parameters. The continuation data comprises information about which tracks will be continued and the ones that will be discontinued. For each track that will be continued, at least one
10 estimate of the frequency location, to which it will be continued is provided.

The output of the control unit 40 along with the current input segment serve as the inputs to the closed loop tracking block 44. The output of the closed loop tracking block 44 consists of track data (indicated using TD in Figure 3) of both the continuing tracks and the newly appearing tracks. The output FD of tracking block 44 in Figure 3 contains auxiliary
15 information in addition to the track data TD. The auxiliary information contains information that is necessary to perform local synthesis and could contain additional information such as the reduction in error that was obtained.

The track data TD is fed to the multiplexer 30, which combines the information in to a multiplex signal which is suitable for transmission.

20 One of the tasks of the control unit 40 is to decide whether a track should be continued in the current segment. This decision is taken on the basis of the available track information thus far including the auxiliary information. The other task is to compute one or more initial estimates of the frequency at T_k for each track that should be continued. This computation can be carried out for varying levels of sophistication, starting from zeroth order
25 extrapolation where only frequency information at T_{k-1} is required, to higher-order prediction using frequency information at T_i with $i < k-1$. In this computation, use can be made from the additional information available at the output of the spectral analyzer 22.

A possible implementation of the tracking block 44 is shown in Fig. 4. The outputs of the control unit 40 and the segmentation unit 20 are input to the continuation
30 tracker 50. The continuation tracker implements a search procedure so as to deliver the optimum parameters corresponding to continuing tracks and the auxiliary information. Using this, a signal s can be synthesized by the synthesizer 52. The output of the synthesizer 52 along with the output of the segmentation unit 20 and possibly the output of the control unit 40 is used by the tracker of newly appearing components 54 to deliver the optimum parameters for

the newly appearing tracks along with the auxiliary information. The outputs of the trackers 50 and 54 are used by the splitter 56 to deliver track data (TD) and feedback data (FD).

The continuation tracker 50 implements a search procedure to deliver an improved estimate of the frequency θ_m at time T_k , along with the optimum amplitude A_m and phase ϕ_m and auxiliary information. The search itself is based upon minimizing the weighted squared error, which can be expressed as:

$$E = \sum_n w_k(n) \cdot [x(n) - s(n)]^2 \quad (4)$$

where w_k is the weighting function in the k^{th} segment, $x[n]$ is the input segment, $s[n]$ is the synthesized segment and n addresses the interval defined by the weighting function. The weighting function is generated on the basis of segment length and the markers $T_k - T_{k-1}$. Let $s(n)$ represent the synthesized signal according to:

$$s(n) = \sum_{m=1}^{v(T_{k-1})} a_m(n) \cos(\phi_m(n)) + b_m(n) \sin(\phi_m(n)) \quad (5)$$

In (5) v is the number of continuing tracks in the current frame and the coefficients $a_m(n)$, $b_m(n)$ and $\phi_m(n)$ in (7) are calculated according to:

$$a_m(n) = a_m(T_{k-1}) + \{a_m(T_k) - a_m(T_{k-1})\} \frac{n - T_{k-1}}{T_k - T_{k-1}} \quad (6)$$

$$b_m(n) = b_m(T_k) \frac{n - T_{k-1}}{T_k - T_{k-1}} \quad (7)$$

$$\theta_m(n) = \theta_m(T_{k-1}) + \{\theta_m(T_k) - \theta_m(T_{k-1})\} \frac{n - T_{k-1}}{T_k - T_{k-1}} \quad (8)$$

$$\phi_m(n) = \phi_m(T_{k-1}) + \sum_{l=T_{k-1}}^{n-1} \theta(l) \quad (9)$$

$$\phi_m(T_{k-1}) = \phi_m(T_{k-1}) \quad (10)$$

$$a_m(T_{k-1}) = A_m(T_{k-1}) \quad (11)$$

Thus the minimization of (6) can be expressed as:

$$\min E \quad (12)$$

$$\theta_m(T_k), a_m(T_k), b_m(T_k)$$

where the minimum is taken over all m according to $1 \leq m \leq v(T_{k-1})$. It is noted, however, that $a_m(T_k)$ and $b_m(T_k)$ appear linearly in $s(n)$. This implies that their optimal values according to the given minimization criterion are the solution of a set of normal equations, thereby simplifying the search procedure and reducing the problem to minimization over $\theta_m(T_k)$.

5 By using (7) to (12), (4) can be rewritten as:

$$E = \sum_n w_k(n) \left[x(n) - \sum_{m=1}^{v(T_{k-1})} a_m(T_{k-1}) \left(1 - \frac{n - T_{k-1}}{T_k - T_{k-1}} \right) \cos(\phi_m(n)) \right. \\ \left. - \sum_{m=1}^{v(T_{k-1})} a_m(T_k) \left(\frac{n - T_{k-1}}{T_k - T_{k-1}} \right) \cos(\phi_m(n)) - \sum_{m=1}^{v(T_{k-1})} b_m(T_k) \left(\frac{n - T_{k-1}}{T_k - T_{k-1}} \right) \sin(\phi_m(n)) \right]^2 \quad (13)$$

Each iteration of the search procedure is started by selecting values of $\theta_m(T_k)$ and calculating the optimum corresponding values of $a_m(T_k)$ and $b_m(T_k)$. In order to calculate the values of $a_m(T_k)$ and $b_m(T_k)$, the following substitutions are performed:

$$\tilde{x}(n) = x(n) - \sum_{m=1}^{v(T_{k-1})} a_m(T_{k-1}) \left(1 - \frac{n - T_{k-1}}{T_k - T_{k-1}} \right) \cos(\phi_m(n)) \quad (14)$$

$$p_{2m-1}(n) = \frac{n - T_{k-1}}{T_k - T_{k-1}} \cos(\phi_m(n)) \quad (15)$$

$$p_{2m}(n) = \frac{n - T_{k-1}}{T_k - T_{k-1}} \sin(\phi_m(n)) \quad (16)$$

$$c_{2m-1} = a_m(T_k) \quad (17)$$

$$c_{2m} = b_m(T_k) \quad (18)$$

Substituting (15) to (19) into (14) gives the following criterion to be minimized:

$$E = \sum_n w_k(n) \left[\tilde{x}(n) - \sum_{m=1}^{2v(T_{k-1})} c_m \cdot p_m(n) \right]^2 \quad (19)$$

10 The minimum of E is found by differentiating (19) with respect to each of the values c_m and setting each derivative to zero. This leads to the following set of equations from which the constants $c_1, c_2, \dots, c_{2v-1}, c_{2v}$ have to be determined.

$$\begin{aligned} \sum_n w_k(n) \tilde{x}(n) \cdot p_1(n) - \sum_n w_k(n) \cdot \sum_{m=1}^{2v(T_{k-1})} c_m \cdot p_m(n) \cdot p_1(n) &= 0 \\ \sum_n w_k(n) \tilde{x}(n) \cdot p_2(n) - \sum_n w_k(n) \cdot \sum_{m=1}^{2v(T_{k-1})} c_m \cdot p_m(n) \cdot p_2(n) &= 0 \\ \vdots &\quad\quad\quad \vdots \qquad\qquad\qquad \vdots \\ \sum_n w_k(n) \tilde{x}(n) \cdot p_{2v-1}(n) - \sum_n w_k(n) \cdot \sum_{m=1}^{2v(T_{k-1})} c_m \cdot p_m(n) \cdot p_{2v-1}(n) &= 0 \\ \sum_n w_k(n) \tilde{x}(n) \cdot p_{2v}(n) - \sum_n w_k(n) \cdot \sum_{m=1}^{2v(T_{k-1})} c_m \cdot p_m(n) \cdot p_{2v}(n) &= 0 \end{aligned} \tag{20}$$

(21) can be cast in matrix notation according to $\bar{\mathbf{d}} - \mathbf{A}\bar{\mathbf{c}} = \bar{\mathbf{0}}$ with $\bar{\mathbf{d}}$, \mathbf{A} and $\bar{\mathbf{c}}$ being equal to:

$$\bar{\mathbf{d}} = \begin{pmatrix} \sum_n \mathbf{w}(\mathbf{n}) \cdot \tilde{\mathbf{x}}(\mathbf{n}) \cdot \mathbf{p}_1(\mathbf{n}) \\ \sum_{n_1} \mathbf{w}(\mathbf{n}) \cdot \tilde{\mathbf{x}}(\mathbf{n}) \cdot \mathbf{p}_2(\mathbf{n}) \\ \vdots \\ \sum_n \mathbf{w}(\mathbf{n}) \cdot \tilde{\mathbf{x}}(\mathbf{n}) \cdot \mathbf{p}_{2v-1}(\mathbf{n}) \\ \sum_n \mathbf{w}(\mathbf{n}) \cdot \tilde{\mathbf{x}}(\mathbf{n}) \cdot \mathbf{p}_{2v}(\mathbf{n}) \end{pmatrix} \quad (21)$$

$$A = \begin{pmatrix} \sum_n w_k(n) p_1(n) p_1(n) & \sum_n w_k(n) p_1(n) p_2(n) & \cdots & \sum_n w_k(n) p_1(n) p_{2v-1}(n) & \sum_n w_k(n) p_1(n) p_{2v}(n) \\ \sum_n w_k(n) p_2(n) p_1(n) & \sum_n w_k(n) p_2(n) p_2(n) & \cdots & \sum_n w_k(n) p_1(n) p_{2v-1}(n) & \sum_n w_k(n) p_1(n) p_{2v}(n) \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \sum_n w_k(n) p_{2v-1}(n) p_1(n) & \sum_n w_k(n) p_{2v-1}(n) p_2(n) & \cdots & \sum_n w_k(n) p_{2v-1}(n) p_{2v-1}(n) & \sum_n w_k(n) p_{2v-1}(n) p_{2v}(n) \\ \sum_n w_k(n) p_{2v}(n) p_1(n) & \sum_n w_k(n) p_{2v}(n) p_2(n) & \cdots & \sum_n w_k(n) p_{2v}(n) p_{2v-1}(n) & \sum_n w_k(n) p_{2v}(n) p_{2v}(n) \end{pmatrix}$$

$$\bar{c} = \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_{2v-1} \\ c_{2v} \end{pmatrix} \quad (23)$$

The value of \bar{c} can now be calculated according to:

$$\bar{c} = A^{-1} \cdot \bar{d} \quad (24)$$

The optimization can be carried out over all tracks simultaneously or track by track. In the latter case, the optimization block decides on the ordering. Such a decision can for instance be made on the basis of the previously strength expressed in A_m . Conventional techniques to terminate the search procedure can be invoked. From a_m , b_m and ϕ_m at T_k the values A_m and

ϕ_m at T_k are calculated according to:

$$\begin{aligned} A_m &= \sqrt{a_m^2 + b_m^2} \\ \phi_m &= \phi_m - \psi_m \end{aligned} \quad (25)$$

Where ψ_m corresponds to the angle of the complex number $a_m + jb_m$.

The tracker of newly appearing components 54 is similar in functionality to the continuation tracker 50. The differences occur due to the fact that the tracker of newly appearing components 54 identifies newly appearing tracks rather than continuing tracks. Accordingly, the target signal against which the error is minimized may be derived from the segment synthesized thus far, $s[n]$ together with the input segment $x[n]$. In its simplest form this may be derived by subtracting s from x . Additionally, the amplitude and the phase values A_m and ϕ_m at T_k are set to 0. During a newly appearing track one has to make an assumption on the track of the frequency or the phase within the current segment. That the frequency is held constant during the birth is a suitable assumption. Thus, in its simplest form, the frequency value θ_m at T_{k-1} may be set in accordance with a constant frequency track.

It is observed that the present invention can be implemented in dedicated hardware, in software running on a DSP or on a general purpose computer. The present invention can be embodied in a tangible medium such as a CD-ROM or DVD-ROM carrying a

computer program for executing an encoding method according to the invention. The invention can also be embodied as a signal transmitted over a data network such as the Internet, or a signal transmitted by a broadcast service.

CLAIMS:

1. Transmission system comprising a transmitter having an audio encoder, said audio encoder comprises segmenting means for dividing an input audio signal into subsequent signal segments, the encoder further comprises track determining means for determining linked signal components present in subsequent signal segments, the transmitter further
5 comprises transmit means for transmitting a signal representing said linked signal components via a transmission medium to a receiver, said receiver comprises receiving means for receiving the signal representing the signal components from the transmission medium, and a decoder for deriving a reconstructed audio signal from said signal representing the signal components, characterized in that the tracking means comprises selection means for selecting linked signal
10 components resulting in a minimum error measure between a synthetic audio signal determined on basis of said linked signal components and said input audio signal.
2. Transmission system according to claim 1, characterized in that the encoder comprises synthesizing means for deriving the synthetic signal on basis of at least one
15 parameter of said candidate linked signal components in two subsequent signal segments.
3. Transmission system according to claim 2, characterized in that that the synthesizing means are arranged for deriving interpolated signal component parameters from signal component parameters corresponding to at least two subsequent signal segments and in
20 that the synthesizing means are arranged for deriving the synthetic signal on basis of the interpolated signal component parameters.
4. Transmission system according to claim 1, 2 or 3, characterized in that the tracking means comprise pre-selection means for selecting a limited number of candidate
25 linked signal components from all possible linked signal components.
5. Transmission system according to claim 4, characterized in that the pre-selection means are arranged to select as candidate linked signal components signal components having a frequency difference smaller than a predetermined value.

6. Transmission system according to claim 1, characterized in that the tracking means are arranged for extending tracks on basis of the parameters of linked signal components already determined.
- 5 7. Transmission system according to claim 6, characterized in that the tracking means are arranged for determining linked signal components on basis of a synthesis of one track.
8. Transmitter having an audio encoder, said audio encoder comprises segmenting means for dividing an input audio signal into subsequent signal segments, the encoder further comprises track determining means for determining linked signal components present in subsequent signal segments, the transmitter further comprises transmit means for transmitting a signal representing said linked signal components, characterized in that the tracking means comprises selection means for selecting linked signal components resulting in a minimum error measure between a synthetic audio signal determined on basis of said linked signal components and said input audio signal.
- 10 15 20 25
9. Transmitter according to claim 8, characterized in that the encoder comprises synthesizing means for deriving the synthetic signal on basis of at least one parameter of said candidate linked signal components in two subsequent signal segments.
10. Transmitter according to claim 9, characterized in that the synthesizing means comprise weighting means for weighting the signal component in the two subsequent signal segments with a corresponding weighting function, and combining means for combining the weighted signal segments into the synthetic audio signal.
- 25
11. Transmitter according to claim 8, 9 or 10, characterized in that the tracking means comprise pre-selection means for selecting a limited number of candidate linked signal components from all possible linked signal components.
- 30
12. Transmitter according to claim 8, characterized in that the tracking means are arranged for extending tracks on basis of the parameters of linked signal components already determined.

13. Audio encoder comprising segmenting means for dividing an input audio signal into subsequent signal segments, the encoder further comprises track determining means for determining linked signal components present in subsequent signal segments, the transmitter further comprises transmit means for transmitting a signal representing said linked signal components, characterized in that the tracking means comprises selection means for selecting linked signal components resulting in a minimum error measure between a synthetic audio signal determined on basis of said linked signal components and said input audio signal.
14. Coding method comprising dividing an input audio signal into subsequent signal segments, determining linked signal components present in subsequent signal segments, transmitting a signal representing said linked signal components, characterized in that the method comprises selecting linked signal components resulting in a minimum error measure between a synthetic audio signal determined on basis of said linked signal components and said input audio signal.
15. Tangible medium comprising a computer program for performing the coding method according to claim 13.
16. Signal carrying a computer program for performing the coding method according to claim 13.

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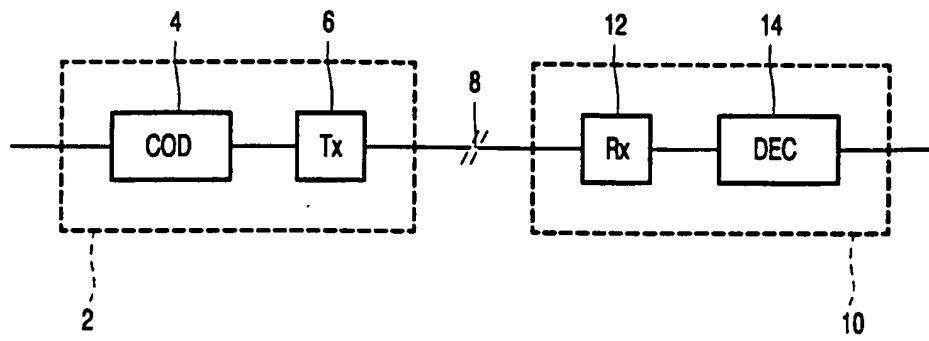


FIG. 1

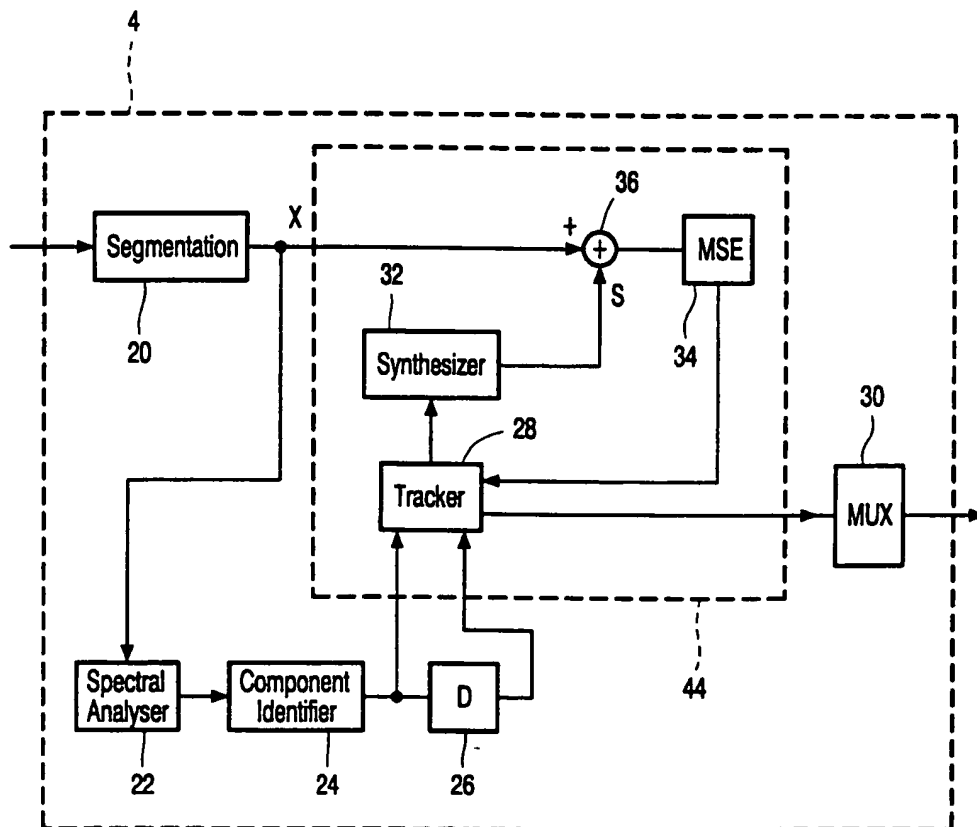


FIG. 2

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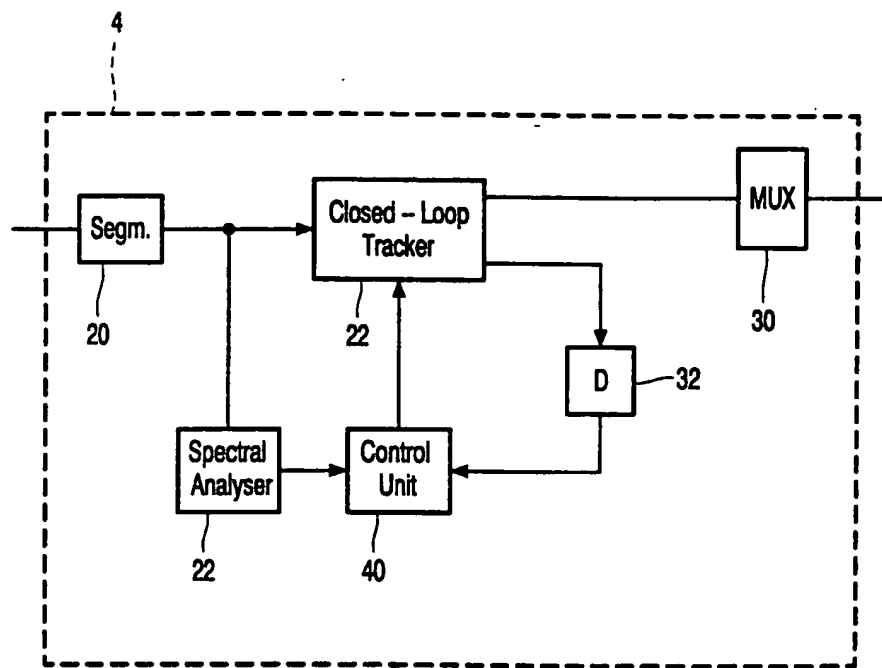


FIG. 3

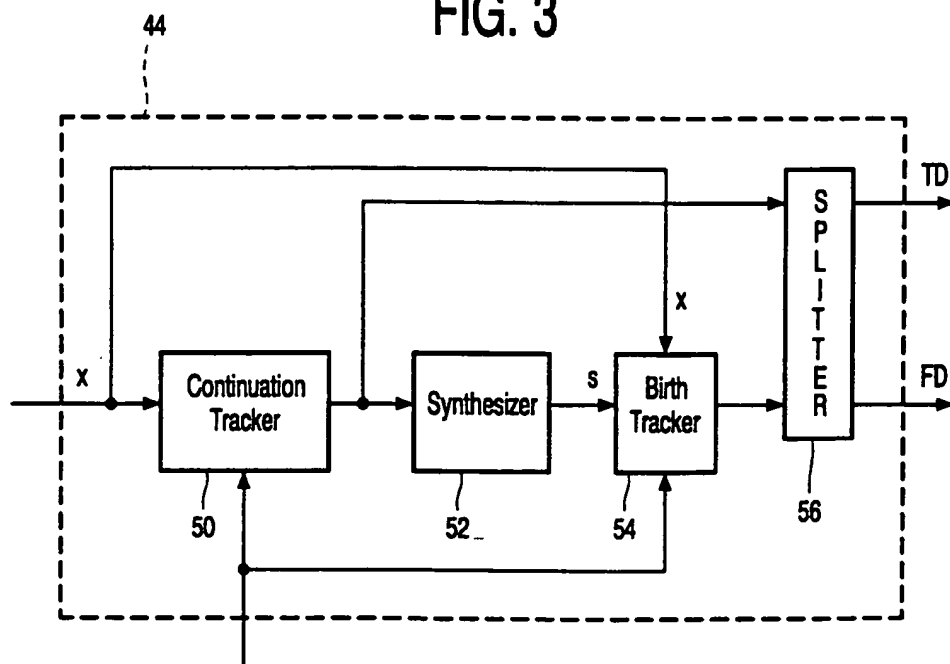


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/05344

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G10L19/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| X | WO 89 09985 A (MASSACHUSETTS INST TECHNOLOGY) 19 October 1989 (1989-10-19) page 3, paragraph 3 page 13 page 15 | 1,8,13, 14 |
| Y | US 4 885 790 A (MCAULAY ROBERT J ET AL) 5 December 1989 (1989-12-05) cited in the application column 2, line 3 - line 13 column 2, line 34 - line 65 column 6, line 24 -column 7, line 23 --- -/- | 1,8,13, 14 |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

9 October 2000

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INTERNATIONAL SEARCH REPORT

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| C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT | | |
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| Y | US 5 504 833 A (GEORGE E BRYAN ET AL) 2 April 1996 (1996-04-02) column 2, line 51 - line 60 column 7, line 27 - line 39 column 9, line 33 - line 67 column 21, line 44 - line 51 ---- | 1,8,13, 14 |
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 00/05344

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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